Fermilab

PPD/MD/Engineering Analysis Group

A Preliminary Stress Calculation for the Cell Structure Used in Liquid Scintillator (Off-Axis)

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The Vertical Cell

For the vertical cell, we could assume that the liquid weight will be holding by themselves. Then, the only load seen by the sidewall will be the hydrostatic load. The Table 1 shows the maximum stress for a given wall thickness based on 17.5 m x 17.5 m plane, proposed in reference (1).

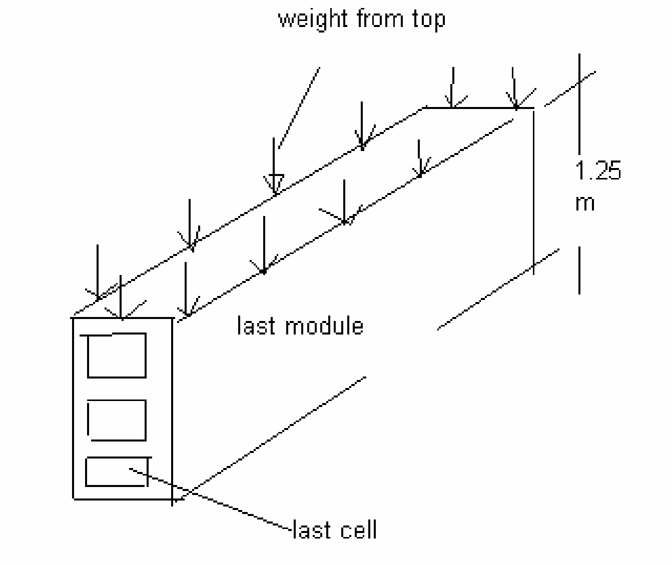
Table 1 The Vertical Orientation for 17.5m x 17.5m Plane
With 4.5 cm Cell Size

Wall Thickness (mm)	Maximum Stress (psi)
1	21,169
2	5,292
3	2,352
4	1,323

The Horizontal Cell

For the horizontal cell, there will be two possible scenarios. The first one is to assume the liquid holding itself within its own module only. The load transfer between modules is primarily through the sidewall. Therefore, the total load at the lowest cell will be the hydrostatic load at 1.25 (m) plus the weight from top modules as following:

$$\sigma_t = \sigma_h(1.35m) + \sigma_w(weight)$$



where $\sigma_h = \dfrac{M}{S} = \dfrac{p*l^2}{12} \Big/ \dfrac{b*t^2}{6} = \dfrac{1.49x1.772^2}{12} \Big/ \dfrac{1*0.0787^2}{6} = 378\,psi$

$$\sigma_w = \frac{W}{A} = \frac{(166+973)*14*9.8}{2*17.5*0.002} = 2.23e6(pascal) = 323\,psi$$, then

The total stress for horizontal orientation with t=2 mm will be

$$\sigma_t = \sigma_h + \sigma_w = 378 + 323 = 701\,psi$$

The second scenario, which is most unlikely case, is to assume the liquid holding themselves just like the vertical one. The reasoning is that the cell divider could be very flexible. The load transfer is primarily relied on the liquid itself not sidewall. Then, the maximum stress for sidewall will be the same as the vertical orientation as listed in Table 1.

Conclusion

The conclusion from this prelimary study shows that the vertical cell will be the driving force for the design of the wall thickness. In general, the tensile strength for PVC material is ranged from 5,000 psi to 12,000 psi, depended upon of the its material and the fabrication. As an example, if we use a PVC with 20% glass fiber reinforced, the tensile strength is about 10,000 psi. By assuming a safety factor of 2, the allowable will be 5,000 psi. The 2 mm wall thickness will be adequate.

Reference

"An Alternative Version of a Liquid Scintillator Detector: Totally Active Configuration". Stan Wojcicki, Stanford University, Off-Axis-Note-scint-28, Feb. 21,2004

Appendix A : The detail calculation for the vertical orientation

Case 1: Assuming all modules are continuously stacking up (gluing) together to form a 17.5 m x 17.5 m plane

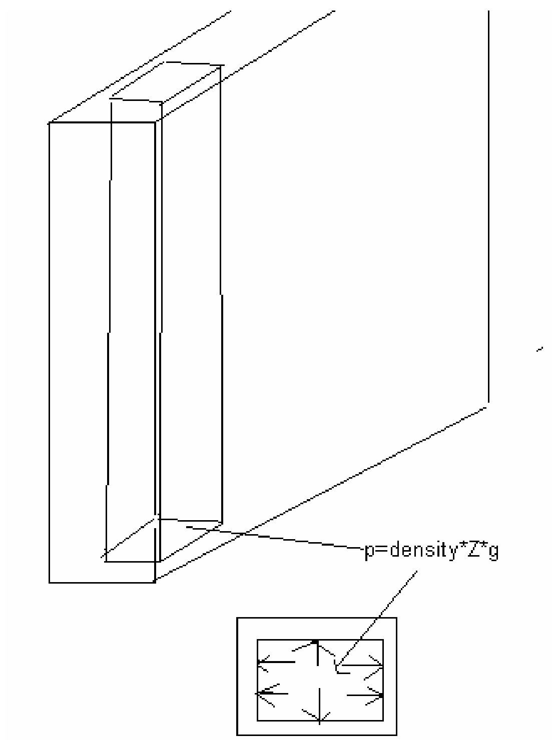
Given: mineral oil SG=0.84

density		**p hydrostic pressure at 17.5 m**	p=density*g*Z(17.5 m)
840	kg/m^3	144060 pascal	or
		20.90856 psi	

For a simple model, a square box with 4.5 cm length subjected to20.9 psi pressure with 2 mm wall thickness

q		a		b	
144060	pascal	4.500	cm	4.500	cm
20.90856	psi	1.772	inch	1.772	inch

t (wall thickness)		moment	S	maximum bending stress		Maximum deflection			
1.000	mm								
0.039	inch	5.47	0.000258	**21169.92**	psi	**0.105485**	inch	2.68	mm
2.000	mm								
0.079	inch	5.47	0.001033	**5292.48**	psi	**0.013186**	inch	0.33	mm
3.000	mm								
0.118	inch	5.47	0.002325	**2352.213**	psi	**0.003907**	inch	0.10	mm
4.000	mm								
0.157	inch	5.47	0.004133	**1323.12**	psi	**0.001648**	inch	0.04	mm



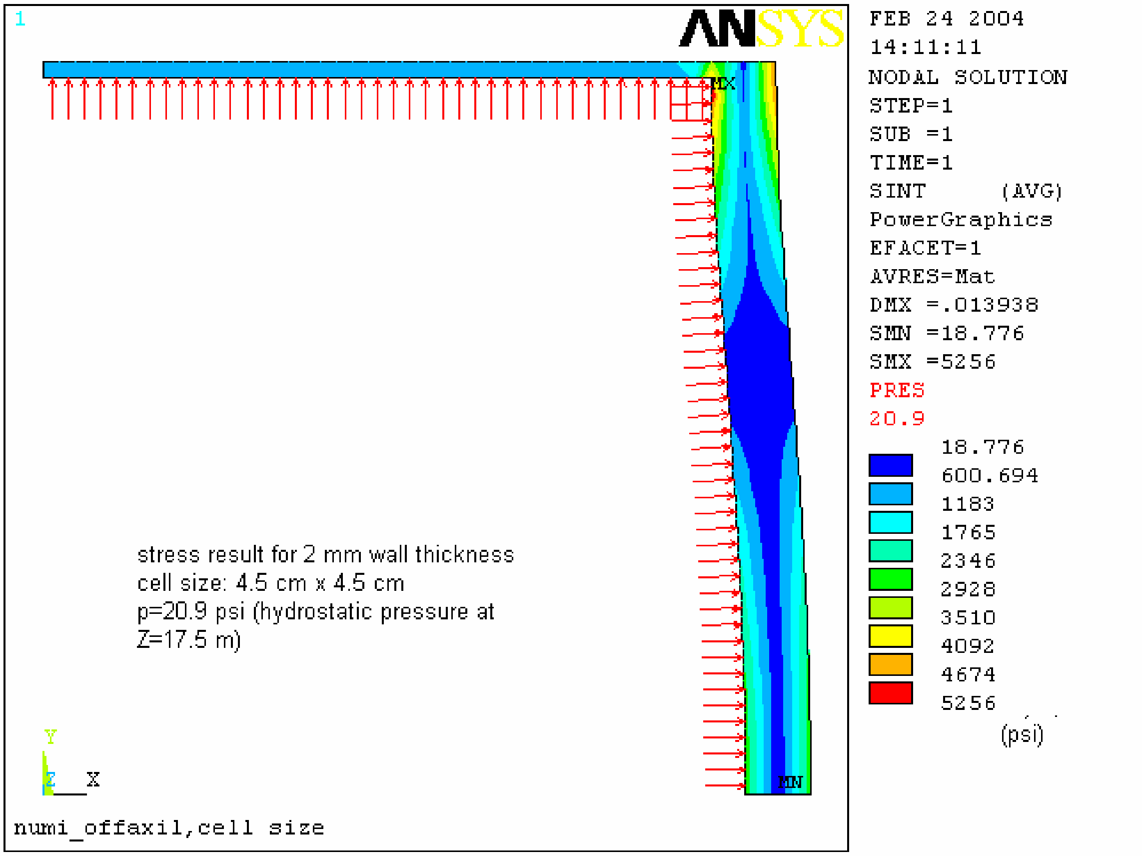


Figure 1 The stress result from ANSYS for a t=2 mm